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Procedure for making draft tests of plows, directions for making square yard harvests of legumes, and description and use of soil sampling tube

Prepared by

The Bureau of Agricultural Engineering,
U. S. Department of Agriculture

in cooperation with the
Ohio Agricultural Experiment Station

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INTRODUCTION

The following suggestions for making draft tests of plows and plowing equipment are the outgrowth of a series of conferences held in Ohio during 1932 between members of the staff of the Division of Mechanical Equipment, Bureau of Agricultural Engineering, U.S.D.A., stationed at Toledo, Ohio, and of the Departments of Agricultural Engineering, Agronomy, and District and County Experiment Farms of the Ohio Agricultural Experiment Station. The method of procedure was developed in an effort to make possible the correlation of the data obtained in draft tests at different locations and by different individuals in this State. While a number of the points have been verified, many of them represent only the combined judgment of the group and so can only be considered as tentative suggestions. Further research may make possible the elimination of a number of the laboratory determinations on soils but it seemed best to make the studies inclusive until such information is at hand. The problem of adequately sampling soils in draft testing is one that can only be satisfactorily answered from field studies.

The engineering phases of this report were prepared by Messrs. I. F. Reed of the Bureau of Agricultural Engineering and N. R. Baer of the Agricultural Engineering Department, Ohio Agricultural Experiment Station, while the soil phases were prepared by Richard Bradfield and G. W. Conrey of the Department of Agronomy, Ohio Agricultural Experiment Station. Mr. J. S. Cutler of the Ohio Agricultural Experiment Station acted in the capacity of coordinator.

Uniform Conditions. -- The importance of selecting as uniform an area as possible for making the tests is well known, yet a resume of the factors making for uniformity in relation to draft tests may not be out of place.

The fact that the topography of a field is fairly uniform does not in itself insure a uniform soil type. Many soil differences are the result of only slight changes in elevation barely discernible to the eye. The type of cover, unless it is the factor being studied, should be as uniform as possible, as the cover has been of more importance in some Ohio tests in its effect on draft than the soil itself. The moisture content should be as uniform as possible. In tiled land the moisture content varies appreciably with nearness to the tile. This factor must be taken into consideration where the plow furrows parallel the tile lines. Where the draft of different kinds of plows or plowing equipment is being compared and only a relative ranking desired, these factors become less important, provided conditions are comparable.

Making Draft Tests

The procedure to be used and the information and data to be recorded on all draft tests in Ohio are as follows:

I. Field History

A. Topography and Drainage (Natural and artificial)

B. Rotation - Plowing schedule and crops for several years previous to year of test

C. Crop cover at time of plowing:

Record whether plowing is being done in sod, stubble, cornstalks, etc. If clover or alfalfa sod is being plowed, root harvests should be made to show the quantity and number of roots per unit of area. (See memorandum on making root harvests, pages 12-15.)

D. Treatments:

1. Mechanical:

Record any treatments on the field previous to plowing, such as disking, etc. Show also what power unit is used for the pretreatments so as to determine the possible packing effect it may have.

2. Soil:

Record time and method of application and quantities applied of lime, crop residue, manure, or fertilizers.

II. Weather History

A. Daily rainfall data for a period prior to time of test. This can usually be obtained from a nearby official weather station.

B. Seasonal weather data. Record any unusual condition.

III. Studies on the Soil Before Plowing - Sampling

A. When to sample

Immediately ahead of the plow before the soil has been affected by either tractor or plow, unless study is to be made of packing effect of prime mover.

B. How to sample

a. For apparent specific gravity and moisture determinations for the different layers in the furrow slice a small, thin-walled tube, bevelled on the outside, of the type recommended by Kopecky (4). Dimensions should be roughly 10 cm. long, 10 $cm.^2$ in cross section, giving a volume of about 100 cc.

b. For other studies. A cylindrical sampling tube of the type shown in Figure 3 will probably be easier to manipulate and give a less distorted sample than the auger commonly used.

C. How many samples

About twice as much soil should be secured as is necessary for making all the studies contemplated. The exact number of samples will vary with the size of tube used and with the number of determinations to be made. In any case, at least triplicate samples from each visibly different area or horizon of consequence in the area being plowed should be obtained.

D. Where to sample

The position from which each compound sample was taken should be carefully noted. Plow draft studies indicate that a much better picture of soil conditions can be obtained by the construction of an isodyne map of the area. The locations of the samples is necessary in order to correlate the physical characteristics of the soil with the plow draft at that particular spot. It is our firm belief that the near random sampling of a field to obtain a representative average of the field would be of much less value.

E. What depth to sample

Quite often, especially in early spring, there are important structural differences between the top few inches of soil and the bottom of the furrow slice. The apparent specific gravity and moisture determinations should be taken on each visibly different layer. If the soil is uniform throughout the plow depth, a single sample through this layer would be adequate.

IV. Studies on the Soil After Plowing

Careful observations should be made of the condition of the soil after plowing, noting especially the granulation and its general structure.

V. Power Source

A. Make, type, size, and serial number of tractor

B. Wheel and lug equipment

VI. The Plow

A. Frame:

1. Make, type, number of bottoms, and weight

B. Bottom:

1. Type and size

2. Type, material, and condition of share

State if stellited or sharpened. It is recommended that sharp, new or stellited shares be used.

C. Equipment:

1. Colter -- size, sharpness, type and condition of bearings. Rolling colter only should be used for all draft tests except when measuring the effects of attachments upon the draft of plows.

2. Other equipment -- description.

D. Adjustment:

1. Set colter just wide enough so the plow will leave a clean cut furrow wall and to approximately 2/3 the depth of plowing, if possible.

2. Hitch point to power unit should be near the line of draft for the plow, that is, about 1/6 the width of cut of the bottom to the right of the landside for single bottom right-hand plows and proportionately located for multiple bottom plows. This may throw excessive side draft into the power unit, but should be tolerated if possible in order that all plows may be tested under nearly the same conditions.

3. Hitch as high on the power unit and as low on the front end of the plow as is possible and still have the plow maintain the desired depth. This tends to remove the weight from the front wheels of the plow and lessens the tendency of the plow to nose. The plow should carry some weight on the landside or on rear wheel if the plow has been so designed.

4. Adjust plow to cut rated width.

5. Adjust plow to maintain uniform depth. It is recommended that the depth be maintained at $6\frac{1}{2}$ to $7\frac{1}{2}$ inches where factors other than depth are being studied. Keep above old plow sole unless its effects on draft are being studied.

VII. Records and Measurements

A. Records

1. Height from plane of cutting edge of share (bottom of furrow) to hitch point on front of plow. (A-Fig. 1).

2. Height from plane of cutting edge of share to hitch point on power unit, that is, the foremost pivot point in the hitch. (B-Fig. 1).

3. Length of floating hitch link including dynamometer unit or portion thereof that floats with hitch. This is the distance from the pivot point in the hitch on the front of the plow to the pivot point on the power unit. (C-Fig. 1).

4. Distance hitch point on power unit is from wall of open furrow. (D-Fig. 1).

5. Colter setting:

(a) Height of cutting edge of colter above plane of cutting edge of share. (E-Fig.1)

(b) Fore and aft relation of hub of colter to point of share. (F-Fig. 1).

(c) Distance between plane of the colter and the plane of the landside of the bottom. (G-Fig. 1).

6. Adjustment of other attachments when used.

B. Measure:

1. Speed of plowing in miles per hour

2. Slippage of power unit, if evident.

3. Depth of plowing:

Measure the depth of plowing to the nearest quarter inch at enough points to establish a usable average. The best method found thus far for making these measurements is by use of the combination width and depth gage shown in Fig. 2. If this type of gage is not available the same results may be obtained by use of a straight edge and rule. Lay the straight edge on the unplowed ground, allowing one end to protrude over the open furrow, then measure from its lower edge to the bottom of the furrow.

4. Width of cut:

As in the case of depth, measure at enough points to establish a satisfactory average for the width of cut. Width measurements may be obtained by use of the above-mentioned gage if available, or by setting a series of stakes a known distance from the furrow wall before making a test, then measuring the distance from the new furrow wall to the stakes. The difference in these measurements is the width of cut.

Note: It is suggested that the draft of plows be calculated to the pounds draft per square inch of furrow cross section basis.

VIII. Tentative Suggestions Regarding Laboratory Studies on Soils from Draft Tests

1. Apparent specific gravity. This determination is of great importance. If the volume of the furrow slice is determined from the dimensions of the furrow slice and this value multiplied by the apparent specific gravity of the soil and the product added to the water content of the soil, the weight of material which is lifted and inverted by the plow will be obtained. The apparent specific gravity is determined from the oven dry weight of a known volume of the soil in its undisturbed natural state. Great care must be taken to avoid any alteration of the structure of the soil during the sampling process. The sampling tube should be thin, highly polished on both inside and outside and the inside diameter of the cutting edge should be slightly smaller than that of the rest of the tube. (See (a) page 3.)

2. Moisture content. Moisture determinations might be advantageously made on the samples used for the apparent specific gravity determination. Moisture content should be determined from the loss in weight on drying to constant weight at 105 to 110° C. It should be expressed as per cent of the oven dry weight of the soil.

3. Mechanical analysis. Some knowledge of the physical make up of the soil is highly desirable. For present purposes the well known hydrometer method of Bouyoucos (3) is probably sufficient in most cases.

4. Moisture equivalent. The amount of water which a soil is capable of holding against a centrifugal force of 1000 x gravity is often a very useful single valued expression for differences in physical properties. The technique is simple and fairly well standardized. (For a simplified method using the ordinary laboratory centrifuge see Reference 5). It has been shown that the values obtained with many soils are higher if made on

samples taken directly from the field than if made on samples which have been allowed to air dry. The values obtained on the samples fresh from the field would probably be of more value for use in connection with plowing tests.

5. Organic matter. Some knowledge of the organic matter content of the soils should be obtained, in view of the widespread idea that organic matter tends to reduce the draft of tillage implements. Ignition loss should probably be determined in the light of Keen's experiments but it cannot safely be used as a criterion of the organic matter content of heavy soils because of the large amount of combined water contained in oven dry samples of such soils. The rapid approximate methods proposed by Schollenberger (Soil Science 24, 65-8, 1927), which can be made in 10 minutes and which requires no special equipment, is probably the best for use in this type of study.

6. Ignition loss. Loss in weight on ignition to constant weight at 700-800° C. should be determined for the reason mentioned above.

7. Atterberg plasticity constants. It is admittedly difficult for different workers in different laboratories to obtain close agreement for the Atterberg constants when working on identical soil samples. These constants have, however, sufficient promise of value in connection with plowing tests to justify their determination in a series of orienting experiments (2). Detailed directions for determining lower plastic limit, upper plastic limit, and plastic range are given by Russell and Wehr (6).

Upper plastic limit. The upper plastic limit of a soil is that moisture content, expressed as a percentage of the weight of the oven-dried soil, at which the soil will just begin to flow when severely jarred.

Lower plastic limit. The lower plastic limit of a soil is the lowest moisture content, expressed as a percentage of the weight of the oven dried soil, at which the soil can barely be rolled into a wire.

Determination of plasticity number or plastic range. The plasticity number of a soil is the difference between its upper plastic limit and its lower plastic limit. The location of the plasticity constants on the moisture scale is also significant. For example, two soils may have essentially similar plasticity numbers, but the location of the upper and lower limit on the moisture scale may be different.

Example:

Lower plastic limit	Upper plastic limit	Plasticity number
20	40	20
30	50	20

8. Sticky point. Keen (7) is inclined to attribute some value to the "Sticky point" as a constant for comparing soils of different texture and for predicting their behavior when subjected to tillage implements at various moisture contents. The sticky point is defined as the moisture content at which a thoroughly kneaded soil is just not sticky to the fingers or mixing tool. It represents a fairly well defined point. In the case of soils containing large amounts of organic matter and in very heavy soils ample time should be given for the added water to penetrate the finer interstices between the colloidal particles.

9. Structural analysis. The mechanical analysis mentioned above should be supplemented with a study of the size distribution of the natural, fairly resistant structural particles. There are in soils unquestionably a large proportion of compound particles which maintain their identity throughout all of the usual cycle of changes to which a soil is subjected.

They are destroyed more or less only when subjected to processes which result in "puddling". Satisfactory methods for making such analysis have not found their way into common usage. The elutriator method used by Baver (1) seems to be as promising as any yet proposed.

10. Flocculation with lime. There is a widespread belief that the addition of lime to a soil tends to reduce the draft of plowing. The limited amount of experimental evidence available indicates that ordinary small applications of lime have little or no effect. The application of larger amounts sufficient to produce a slight but fairly durable surplus of $CaCO_3$ in the soil seems to be beneficial from the physical point of view. Some idea regarding the relative positions of different soils to this point at which an improvement due to liming is to be expected could probably be obtained by a serial experiment in whick small samples of the soil are treated with increments of $Ca(OH)_2$ and after allowing the $Ca(OH)_2$ to react with the soil converting the excess into $CaCO_3$ and $CaHCO_3$ by bubbling air through the suspension. The minimum amount of Ca giving complete flocculation on standing for a few hours would probably be a satisfactory index of the state of lime saturation of the soil.

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Directions for Making Square Yard Harvests of Legumes

(Original material prepared by C. J. Willard, Ohio Experiment Station)

The square yard harvests have been made through the use of a square yard iron. A 3/8 inch iron rod is bent in the form of a U, measuring 3 feet on a side and having the ends turned up. The loose side is pointed on one end and hooks over the upturned ends, completing the square yard. This equipment has proven satisfactory for harvests of legumes. Where harvests are desired of blue grass or similar sods, only a square foot is used because of the difficulty in washing and cleaning a larger sample, on account of the large mass of fibrous roots. If really accurate results are desired, corrections should be made. See: Willard, C.J., and McClure, G.M. - The Quantitative Development of Tops and Roots in Blue Grass with an Improved Method of Obtaining Root Yields, J. Am. Soc. Agron. 24, 7 (1932).

1. Care should be taken to choose as representative an area as possible, considering density, height, and vigor of the stand. Triplicate harvests from such areas will give fairly accurate data.

2. If the forage is more than a few inches high, cut the forage at one side of the area selected; then push the upturned ends of the iron through the forage along the ground until the closed side of the iron is in place against the uncut edge of the area selected. Run the loose side of the iron through the forage at the opposite side of the area and hook over the upturned ends, completing the square yard. If the forage is short, the iron may be simply dropped on the selected area.

3. Some tops will usually be mashed by the iron so that they are out of the plot when they should be in, or in when they should be out. The location of the roots determines where the stems are to be considered. All stems from roots inside the iron go in the sample. Go around the borders of the area, pulling the tops in or out of the plot as may be necessary.

4. Cut a mark in the soil all around the plot even with the outside edge of the iron, using a sharp straight spade. Cut straight down at least an inch and push the earth out. Do not merely scratch along with the corner of the spade.

5. If the tops are over 8 inches high, cut them with a sickle and tie in a labeled bag or cloth. If shorter than this, they should be left on the roots and removed later with the knife or shears. In this case, the square yard area should not be tramped on in harvesting.

In the very early spring (before April 15), when green manure samples are wanted, tops and roots may be harvested together and not separated. However, the dead tops or stubble of last year should be carefully cleaned off the square yard before digging it. After this time, tops should always be cut fcom the roots, as described later. Samples of tops plus roots have almost no value after very early spring, because of the great differences in the composition and relative amounts of the two parts.

6. Dig a trench clear across and outside of one side of the iron. This should be a spade's width or more, and one foot in depth. Make the wall of this trench next to the square yard area straight and perpendicular, to give an accurate starting point for digging the square yard. The iron may now be removed.

7. Dig out the square yard area, breaking the soil at first into this trench. Force the spade into the ground vertically. The easy, natural way to spade is with a slanting out, but doing this will cut off many roots. Force the spade to full one-foot depth; then remove the loosened chunk of soil and break it up carefully, picking out the roots. Shake off as much dirt as possible. Place the roots in old cloths or sacks, label, tie up, and protect from drying out, either by using wet cloths, or covering with green forage. If washing is delayed, keep the roots damp and cool by sprinkling, keeping covered, and, in summer, storing in as cool a place as is available.

There is no better time to fill the hole than just after it is made. Put the dirt back!

8. Washing the roots thoroughly is as important as digging them accurately, and is not difficult to do, even if running water is not available. Have two tubs or buckets of water. Empty a sample of roots into one, let them soak a little and then wash thoroughly, rubbing all dirt off the roots with the hands, until no dirt is left on them except the film from the muddy water. Then transfer the entire sample to the other tub, and rinse thoroughly. The samples should be as clean as if prepared for the kitchen. Let the next sample soak in the wash water while rinsing the first sample, but be careful to avoid mixing.

Perhaps the most serious difficulty with square yard samples has been the way the roots have been washed. After the roots have dried, it is not possible to wash them, so unsatisfactory washing cannot be corrected later. It must be done right at the time of digging.

9. If the stubble or small tops are to be cut from the roots, this is done just after washing. Pruning shears are the best tool for this work, but scissors or sharp paring or pocket knife can be used. Be careful to cut exactly at the division of root and top. It is easier to cut a little way down on the roots, but this makes seriously inaccurate results. In case of doubt, be sure to leave enough on the roots; this last applies especially to old alfalfa, which develops a distinctly irregular "crown". This "crown", but no actual stubble, should be left on the roots.

10. The samples must be well dried; this is sometimes difficult to do. The samples should be spread out thin, and turned or loosened at least once a day, or more often if spread in the sun. It is highly desirable to dry as quickly as possible; so, if the samples can be given at least their first drying in the sun, this should be done. However, losses from wind and livestock must be prevented. A well ventilated attic, mow, or granary is a desirable place to spread out samples for drying.

When partially dry, but still tough, they can be placed in the special sample bags and hung up to complete the drying.

Soil Sampling Tube

The soil sampling tube shown in Figure 3 was designed and is used by the Division of Mechanical Equipment, Bureau of Agricultural Engineering, Toledo, Ohio. This type of sampling tube has been found very convenient for rough sampling for moisture and apparent specific gravity determinations, but probably would not be desirable for obtaining undisturbed samples for structural studies. For these studies the sampling tube recommended on Page 3 of this report should be used.

This soil sampling tube consists essentially of the tube A, stop C, and rod F. The tube A is made from a piece of 2-inch 1/16-inch wall steel tubing 12 inches long. This tube can be shaped easily and quickly by the following procedure. Chuck one end of the piece of tubing in a lathe and support it about three inches back from the other end in the steady rest. Clamp a tool holder in the tool post with the back end toward the tubing. Run the lathe slowly and apply a torch to exposed end of tubing until it becomes dull red, then bring back end of tool holder against end of tubing and draw into shape. The tube should be tapered back about one inch and drawn down so the inside diameter at cutting edge is about 1-21/32 inches. Lines are scratched around the tube at one-inch intervals starting from the cutting edge. Polish the tube both inside and out. The stop C consists of a washer four inches in diameter with a 2-1/32-inch hole in it, a clamping ring made from 1 x 1/8" stock, and a bolt with a wing nut. The clamping ring is spot-welded to the washer on the side opposite the bolt.

The rod F consists simply of a 1/2-inch rod upset on one end so that this end may be used to push the soil out of the tube in case it should stick. It is very desirable to have all parts of the soil sampling tube chrome-plated. A .002-inch plate gives a very hard smooth surface and prevents rusting.

When using this tube for sampling for apparent specific gravity and moisture content the stop C is adjusted for the desired depth of sample, and the sampler is then forced into the soil until the stop comes even with the surface of the ground, a hole is then dug down along the side of the tube and the soil cut off even with the bottom of the cutting edge. However, if the samples are to be used for moisture content determinations only the sampling tube may be pulled out without digging along side and cutting the soil off. The soil will break off near enough to the cutting edge of the tube for the moisture determinations, but not accurately enough for specific gravity measurements.

Pint fruit tins are convenient containers for the samples. Since the lids seal them air-tight, sample need not be weighed in the field, but may be taken into headquarters and weighed at the end of the day's field tests.

FIELD DATA SHEET

Draft Tests of Plows — Agricultural Engineering

Soil type ______________________ Test No. ____________

Crop Rotation ______________________ Chart No. ____________

Previous Crop ______________________ Date ____________

Pretreatments ______________________ Series ____________

Remarks ______________________ Plot ____________

______________________ Location ____________

		Depth Inches	Width Inches		Draft Pounds
Bottom	Make				
	Type				
	Size				
Frame					
Attach-ments	Name				
	Adjustments				
	Name				
	Adjustments				
Hitch Adjustment	Vertical — Tractor				
	Vertical — Plow				
	Horizontal				
Power Source	Make				
	Size				
	Lug Equip.				
	Average				

Moisture % ____________

Ap. Sp. Gr. ____________

Atterberg Constants

P_u ______ P_l ______ P_c ______

Bouyoucos Constants

1 Min. ______ 15 Min. ______

1 Hr. ______ 2 Hrs. ______

Sticky Point ____________

Organic Matter ____________

Distance Traveled ____________

Time Required ____________

Speed Miles per hour ____________

Area of furrow slice ___ sq.in.

Av. Draft per sq.in. ___ lbs.

Notes & Remarks ____________

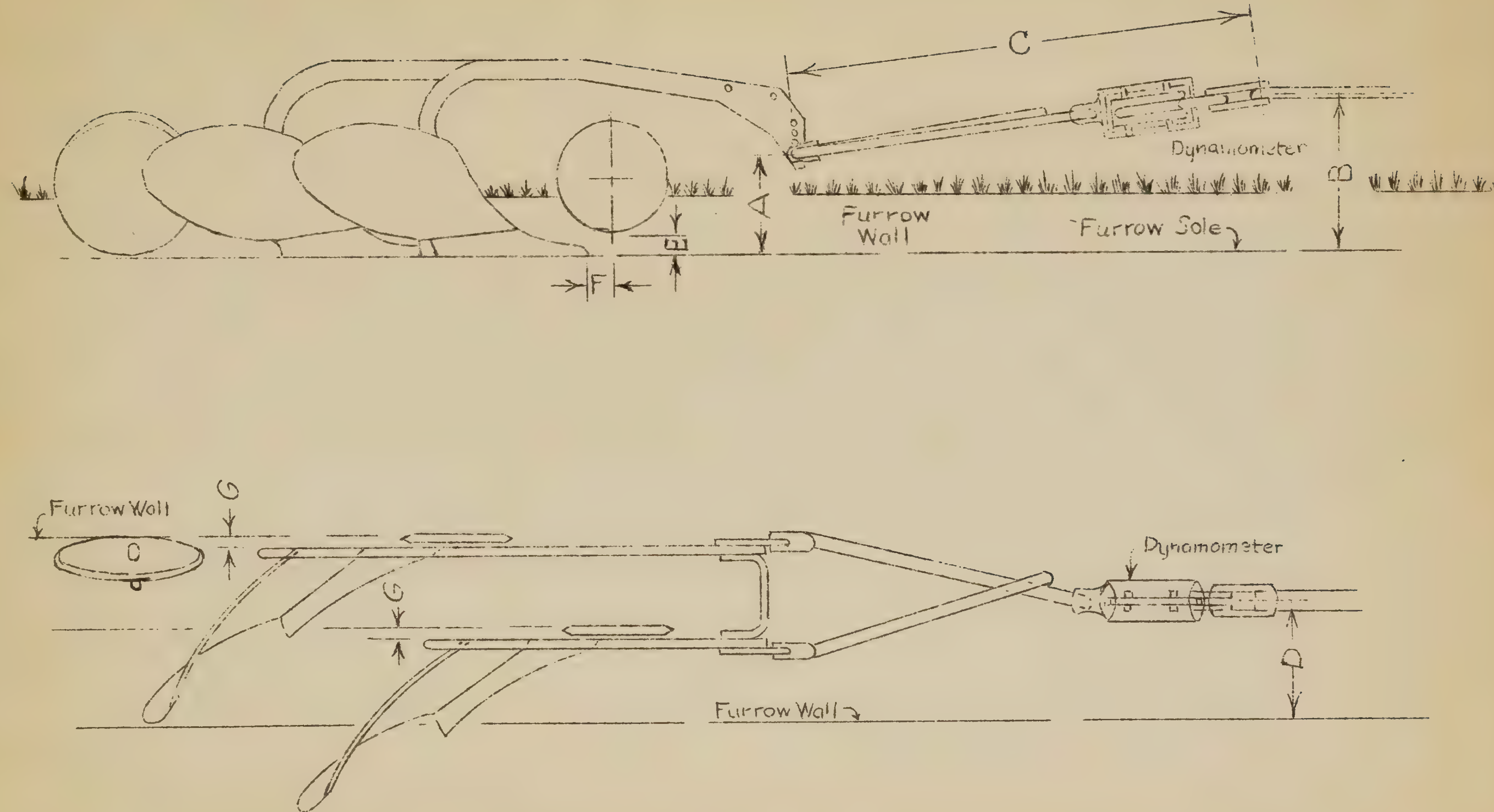

C
Dynamometer
A
B
E
F
Furrow Wall
Furrow Sole
Furrow Wall
G
G
Dynamometer
D
Furrow Wall

Fig. 1

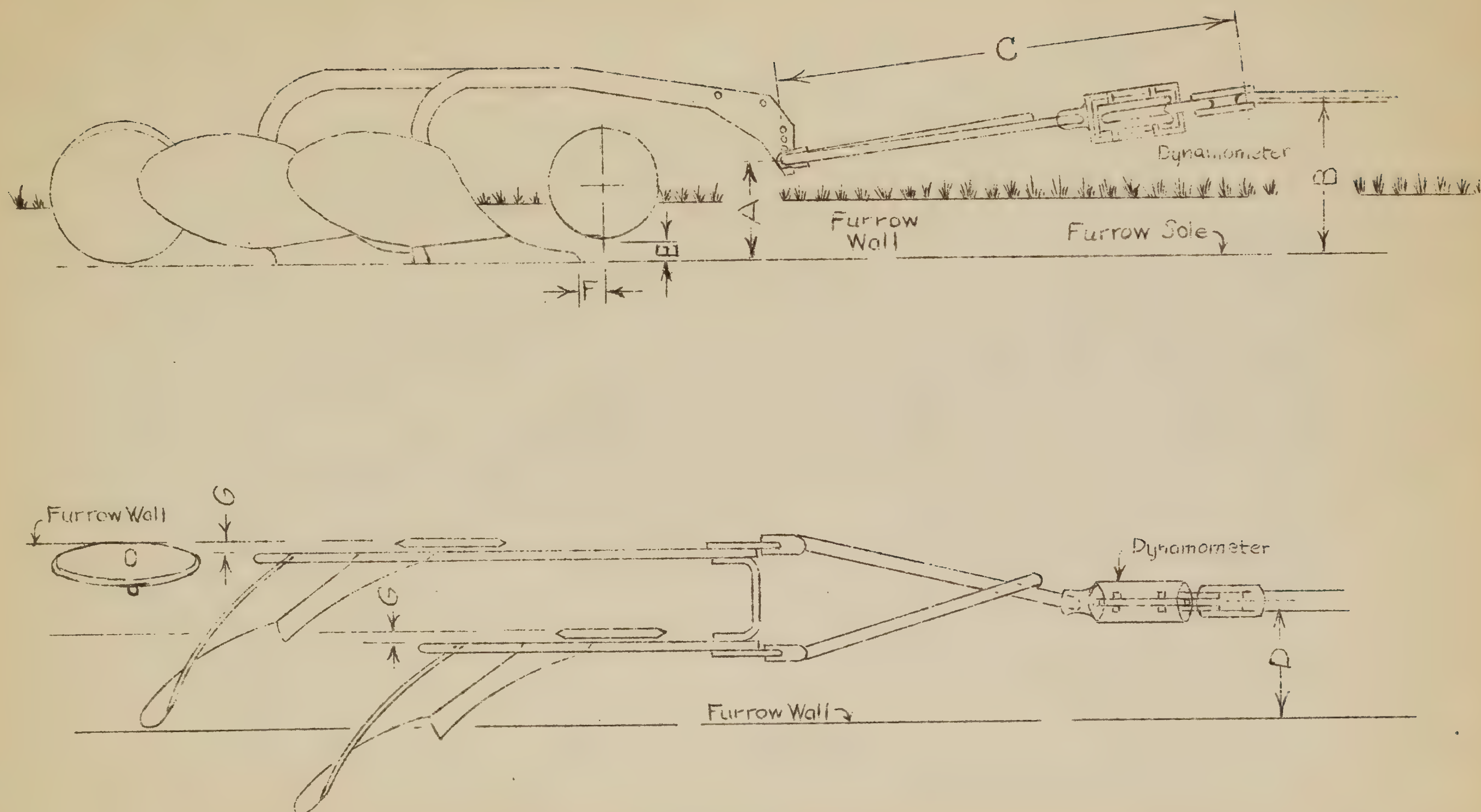
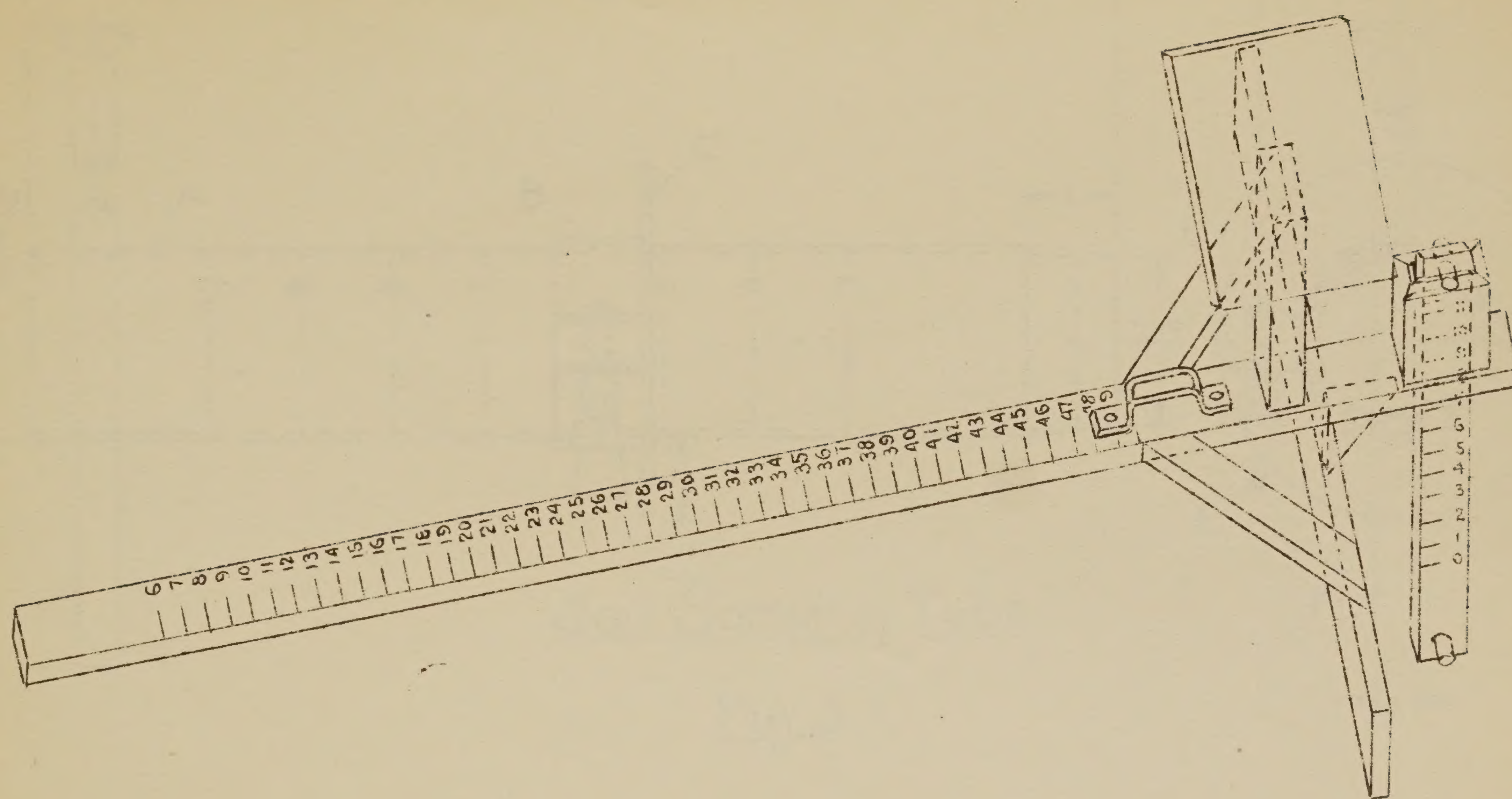

C
Dynamometer
A
B
E
F
Furrow Wall
Furrow Sole
Furrow Wall
G
G
Dynamometer
D
Furrow Wall

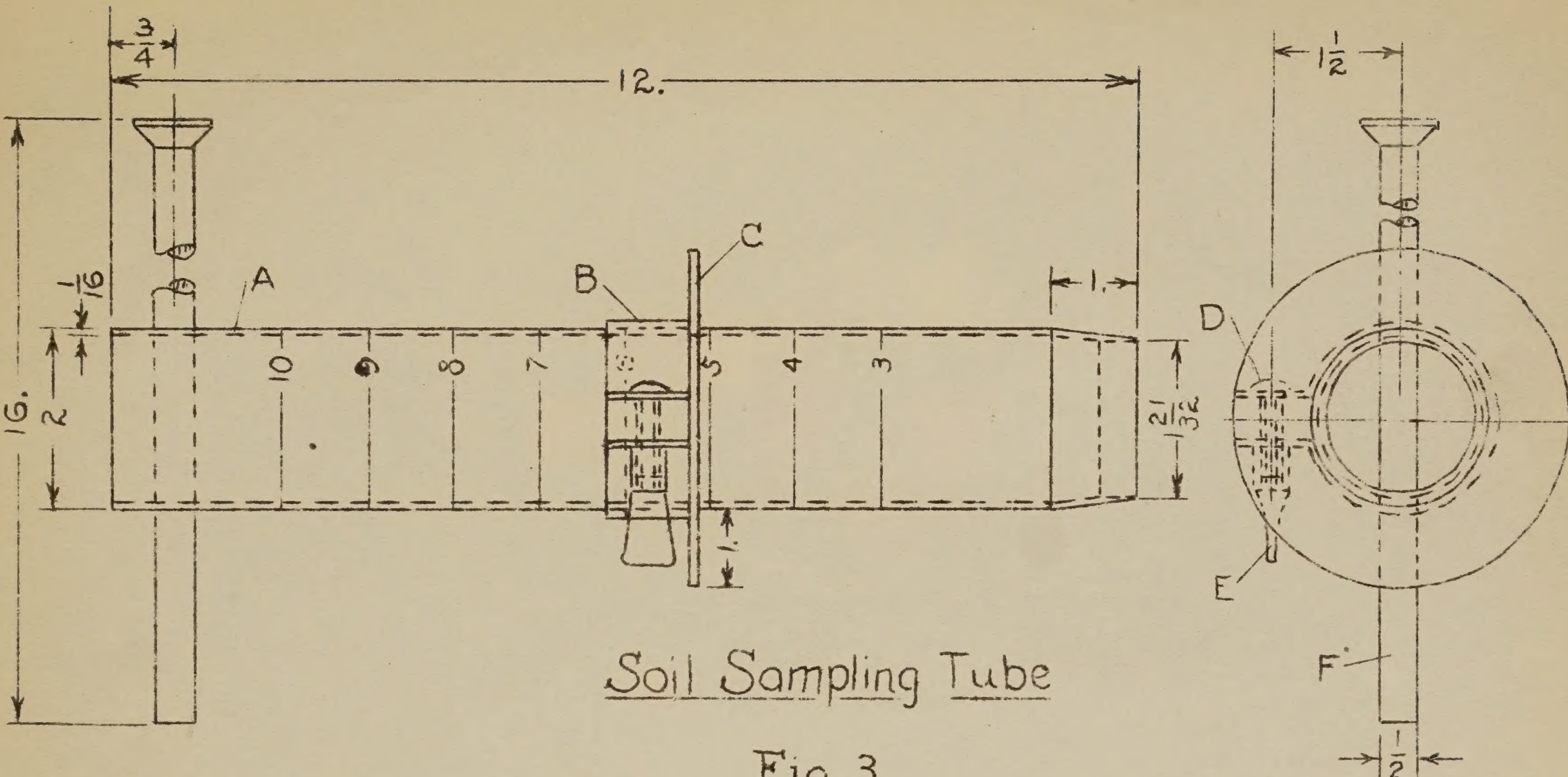
Fig. 1

Detail drawings may be obtained
from Bur. of Agri. Eng. U.S.D.A



Furrow Gage

Fig. 2



Soil Sampling Tube

Fig. 3